TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 470

A COMPLETE TANK TEST OF A MODEL OF A FLYING-BOAT HULL - N.A.C.A. MODEL NO. 11-A

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SUMMARY

Model No. 11-A was designed as an improvement over N.A.C.A. Model No. 11, a complete test of which is described in N.A.C.A. Technical Note No. 464. In contrast with the longitudinal upward curvature in the planing bottom forward of the main step on Model No. 11, the planing bottom of Model No. 11-A was made as flat as practicable. Otherwise, the two models have very nearly the same form.

The results of towing tests made on Model No. 11-A in the N.A.C.A. tank over a wide range of speed, load on the water, and trim angle are presented, both as original test data and as nondimensional coefficients. A comparison is made with similar results from the test of Model No. 11. The practical significance of the improvement obtained is demonstrated by applying the data from the new form to the illustrative design problem used in the note on Model No. 11.

INTRODUCTION

One of the major items on the research program for the N.A.C.A. tank is a study of the behavior of flying-boat hulls on the water. As a part of this program, a family of five models, consisting of a parent form and four systematic variations, has been tested. The parent form is represented by Model No. 11.

It was thought that the fore-and-aft upward curvature in the forebody forward of the step in Model No. 11 was too great and that better performance would be obtained by making the forebody straight for as great a distance forward of the step as was practicable. A new forebody was designed and built in accordance with this idea and assembled with the original afterbody. The combination was designated "N.A.C.A. Model No. 11-A."

This model was tested in the N.A.C.A. tank at Langley Field, Va., over a wide range of speed, load on the water, and trim angle. In addition to providing a direct comparison between the models in question, this sort of "complete" test enables a general comparison to be made with other known types. As the number of such tests on representative hulls is increased, the question of relative merit among them will become increasingly easier to answer. The test data of Model No. 11-A are presented for this purpose, as well as to provide known water characteristics by which the geometric form may be directly applied to a new design. The method for using these data in determining optimum size of hull, angle of wing setting (incidence), take-off time, and length of take-off run is described in detail in reference 1.

DESCRIPTION OF MODEL

Model No. 11-A was made of laminated mahogany to a tolerance of ±0.02 inch on dimensions. The principal lines are shown in figure 1 and complete faired offsets are given in table I. The following particulars apply both to it and to Model No. 11 from which it was derived.

Length (including tail)	8 ft.
Length of forebody	4 ft.
Beam	17 in.
Depth	14 in.
Depth of step	0.56 in.
Dead rise at step	22-1/2°
Included angle between forebody and afterbody	6.5°

The model dimensions and offsets may be readily converted for any size of hull, when the optimum scale ratio is determined.

Since the fore-and-aft curvature in the forebody near the step on Model No. 11 was thought to have an adverse effect on both its resistance and its spray characteristics, the forebody buttocks, keel, and chines of No. 11-A were made without curvature as far forward from the step as was practicable before forming the bow. The cross sections in this region are straight lines. The forward keel line at the step has an angle of 1° with the base line. Near the bow, the chines rise rapidly and the cross sections become hollow.

Aft of the step, Models No. 11 and No. 11-A are identical. The bottom terminates in a relatively narrow "sternpost," aft of which the hull is principally a support for the tail surfaces and may vary considerably among different designs with little effect on performance.

APPARATUS AND TEST METHOD

The equipment of the N.A.C.A. tank for testing models of seaplane floats and hulls is described in reference 2. The value of the data obtained from this tank is greatly enhanced by the use of comparatively large models, which permit more accurate weighing of the forces involved, while the difference between converted test results and actual full-scale forces is reduced.

The small towing gear described in reference 2 was used when testing Model No. 11-A. The desired load on the water, however, was adjusted by means of counterweights instead of by the hydrovane lift device employed when the gross load and get-away speed of a model are specified in advance. In a series of constant-speed runs, simultaneous values of speed, resistance, and draft were taken, as well as the moment required to hold the model at the angle of trim desired. Photographs were taken at desired intervals throughout the test for a study of wave and spray formation. With the model at rest, the longitudinal righting moments and drafts were observed for several loads and angles of trim.

RESULTS

Test data.- Net values of resistance, trimming moment, and draft obtained by deducting the usual towing-gear tares and corrections from the observed data are given in table II for various loads and speeds and for several trim angles.

The air drag of the model is included in the net resistance given. The conversion of the air drag from model to full scale follows the same law as that assumed for the water resistance; hence, the air drag of the full-sized hull should be omitted from the estimated air drag of the airplane when applying these results to a take-off calculation.

The center about which moments were taken is shown on figure 1. The measured moments must be transferred from this point to the actual center of gravity for any given design. Moments which tend to raise the bow are considered positive.

The drafts given in the table are the distances from the free-water surface to the point of the keel at the step.

Figures 2 to 6 were plotted from the data of table II. They show the resistance and the trimming moment plotted against speed with the load on the water as a parameter. Figures 2 to 5 present extensive data for trim angles of 3°, 5°, 7°, and 9°. The curves for the additional trim angles 2°, 4°, 6°, 10°, and 11° in figure 6 were used to assist in the determination of the minimum resistance and the angle at which it occurs for various speeds and loads, as will be explained under Derived data. The drafts, being of secondary importance, were not plotted, but this may readily be done from the data in table II.

The longitudinal righting moments of the model at rest for various displacements are shown in figure 7. The intercepts on the horizontal axis will give the trim angle at rest for the various loads. Here, too, the center of moments is that shown in figure 1 and the righting moments must be transferred to the actual center of gravity of the design that is being considered.

Figure 8 shows the observed drafts at rest plotted against displacement for various angles of trim. Knowing the trim, these curves may be used to draw the water line on the hull profile.

Precision.- The test results are believed correct within the following limits:

Load on water	±0.3 lb.
Resistance	±0.1 lb.
Speed	±0.1 f.p.s.
Trim angle	±0.1°
Trimming moment	±1.0 lb.-ft.

Derived data.- Inasmuch as the hull should run near the best trim angle during take-off, the application of the test results is considerably simplified by cross-fairing the resistance against trim angle. From these curves, the minimum resistance and the trim angle at which it is obtained are found for any speed and load. Figures 9, 10, and 11 are the results of this operation, plotted in nondimensional form so that they may be used for any size of hull and with any consistent system of units. The nondimensional coefficients adopted are as follows:

Load coefficient $C_\Delta = \dfrac{\Delta}{w\ b^3}$

Resistance coefficient $C_R = \dfrac{R}{w\ b^3}$

Speed coefficient $C_V = \dfrac{V}{\sqrt{g\ b}}$

where Δ is the load on the water, lb.

R, resistance, lb.

w, weight density of water, lb./cu.ft.

b, beam of hull, ft.

V, speed, f.p.s.

g, acceleration of gravity, ft./sec.^{2}

w = 63.6 lb./cu.ft. for N.A.C.A. tank water and is usually taken as 64 lb./cu.ft. for sea water.

The application of figures 9, 10, and 11 to design problems is fully described in reference 1 and will not be taken up in this note.

Relative Merit of Model

It was believed that Model No. 11-A, having a forebody with less upward curvature than that of Model No. 11, would show better water performance and spray characteristics. An analysis of the test results shows that this belief was justified and that Model No. 11-A has marked superiority in both respects.

Performance.- A comparison of resistance between models tested by the complete method may be carried out by plotting the nondimensional ratio, load/resistance (at best angle), against load coefficient C_Δ, at representative speed coefficients C_V. This procedure was followed for Models No. 11 and No. 11-A and the results are given in figure 12. Four representative values of C_V were chosen; namely, one at the hump, one where load/resistance is nearly constant over a range of C_Δ, and two well out in the planing region. It will be seen that Model No. 11-A shows considerably greater load/resistance ratios at the lower C_V values and retains its superiority, although to a lesser degree, at higher C_V values. The ratio at the hump for this model remains above 5.0 for practically all loadings found in good practice, and shows improvement of from 22 to 25 percent over that of Model No. 11.

The practical value of such improvement may be shown by reworking the take-off problem in reference 1, using the same method throughout but substituting the data of Model No. 11-A for that of Model No. 11.

In this problem the following design conditions were assumed:

Gross load	15,000 lb.
Wing area	1,000 sq.ft.
Power	1,000 hp.

Effective aspect ratio including ground effect 7.0

Parasite drag coefficient, excluding hull 0.05

Airfoil ... Clark Y (data taken from N.A.C.A. T.R. No. 352, p. 26)

Thrust .... linear variation with speed from 4,000 lb. at 0 f.p.s. to 3,150 lb. at 100 f.p.s.

In the example of reference 1, the size of hull was arrived at by assuming a value of 0.35 for C_Δ at the hump speed, which gave a load/resistance ratio of 4.5 and a beam of 101.5 inches. The superior over-all performance of Model No. 11-A indicates that a smaller hull is permissible. Accordingly, the value of C_Δ at the hump was assumed to be 0.40, which for this form gives a load/resistance of 5.3 (see fig. 12) and a beam of 96.8 inches. This beam was used to obtain the results given below. A still smaller beam was also tried but did not give as good results. Although this latter calculation showed slightly lower high-speed resistance, the advantage was more than offset by a higher hump resistance.

The best angle of wing setting found by the method described in reference 1 was 6.7°. This value was assumed for the calculation.

Using figures 9, 10, and 11 for finding the water resistance and following the method outlined in reference 1, the take-off time and distance were obtained. These values compare with the previous example as follows:

	Model No. 11	Model No. 11-A	Reduction percent
Time, seconds	50	38	24.0
Run, feet	3,120	2,410	22.8

In the preceding calculations, it was assumed that the hull was near the trim angle for minimum water resistance during the entire take-off, and that there was no wind.

There is little difference in the values of maximum trimming moments at the same trim angles between the two forms. Model No. 11-A, however, will be more difficult to hold near the best trim angle at the hump speed since this angle is approximately 2° lower than that of Model No. 11, and a much larger positive moment results from running at the lower angle. For conventional designs, the center of gravity would probably have to be moved forward to attaim this angle.

Spray characteristics.- Model No. 11-A was observed to have a better spray formation throughout the tests. The natures of the sheets of spray, or "blisters", thrown by the two forebodies are shown in figures 13 and 14. A close study of the photographs will indicate the detrimental effect of the curvature found in Model No. 11.

In practice, the blisters from a hull having straight V-sections are often reduced by spray strips fitted to the forebody chines which deflect the water downward as it leaves the hull. The cleanness of running of both Model No. 11 and Model No. 11-A would probably be improved by this means.

Figure 15 shows the appearance of the bow blisters thrown from Model No. 11-A under conditions usually obtained while taxying. It is difficult, however, to judge accurately the seaworthiness of a certain form of bow from tank tests in smooth water.

CONCLUSIONS

The water resistance of Model No. 11-A in the neighborhood of the hump speed and at planing speeds is less than that of Model No. 11 at the same speeds. For the same load on the water, the better form of Model No. 11-A makes it possible to use a smaller hull than is required with Model No. 11. This decrease in size should reduce the weight of the hull and the aerodynamic resistance.

For this type of hull, the tests indicate that longitudinal upward curvature such as is found in Model No. 11 is detrimental to satisfactory performance and spray characteristics.

Compared with other hulls regarding which data are available, Model No. 11-A has excellent characteristics. By the use of the data presented herein, its geometric form may be directly applied to a variety of projected designs.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 7, 1933.

REFERENCES

1. Shoemaker, James M., and Parkinson, John B.: A Complete Tank Test of a Model of a Flying-Boat Hull - N.A.C.A. Model No. 11. T.N. No. 464, N.A.C.A., 1933.

2. Truscott, Starr: The N.A.C.A. Tank - A High-Speed Towing Basin for Testing Models of Seaplane Floats. T.R. No. 470, N.A.C.A., 1933.

TABLE I

Offsets in Inches for N.A.C.A. Model No. 11-A Flying-Boat Hull

Sta. No.	Dist. from F.P.	Distance below base line: Keel	B1 [1]1.50	B2 3.00	B3 4.50	B4 6.00	B5 7.50	Main chine	Cove	Upper chine	Half-breadths: Main chine	Cove	Upper chine	WL1 [a]12.50	WL2 11.00	WL3 9.50	WL4 8.00	WL5 6.50
F.P.	0	4.00						4.00			0.25							
½	2.40	10.43	6.25					5.27			2.25					0.23	0.68	1.34
1	4.80	11.80	8.89	6.97				6.33			3.81				0.38	1.14	2.09	3.55
1½	7.20	12.44	10.38	8.68	7.51			7.19			5.03				1.04	2.24	3.80	
2	9.60	12.83	11.30	9.88	8.77	7.93		7.93			6.00			0.31	1.79	3.49	5.84	
3	14.40	13.29	12.25	11.27	10.37	9.56		9.00			7.25			1.14	3.41	6.12		
4	19.20	13.48	12.70	11.92	11.19	10.49	9.82	9.63			7.94			1.88	4.89			
5	24.00	13.58	12.92	12.25	11.62	10.97	10.33	9.99			8.28			2.43	5.92			
6	28.80	13.66						10.17			8.43							
7	33.60	13.75						10.24			8.49							
8	38.40	13.83						10.32			8.50							
9	43.20	13.92						10.40			8.50							
10 for'd	48.00	14.00						10.48			8.50							
10 aft	48.00	13.44						9.93			8.50							
11	52.80	12.97						9.45			8.50							
12	57.60	12.51						9.16	8.23	8.10	8.10	8.10	8.40					
13	62.40	12.04						9.16	7.57	7.09	6.97	6.97	8.11					
14	67.20	11.58						9.48	7.21	6.17	5.07	5.07	7.58					
15	72.00	11.11						10.04	7.11	5.38	2.59	2.59	6.77					
stern-post	76.00	10.74 7.24						10.66	7.16		.20	.20						
16	76.80	7.04								4.65			5.78					
17	81.60	5.91								4.00			4.61					
18	86.40	4.77								3.40			3.31					
19	91.20	3.64								2.85			1.90					
20	96.00	2.50								2.33			.40					

[1] Distance from center line (plane of symmetry) to buttock (section of hull surface made by a vertical plane parallel to plane of symmetry)

[a] Distance from base line to water line (section of hull surface made by a horizontal plane parallel to base line)

Elements of stations 6 to 20 inclusive are straight lines

TABLE II

Test Data for N.A.C.A. Model No. 11-A Flying-Boat Hull

Kinematic viscosity = 0.00001446 $\frac{ft.^2}{sec.}$

Test dates: April 13-15, 1933
Water temperature: 50° F.
Tank water density: 63.6 lb. per cu.ft.

Trim angle, τ = 2°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
10	42.4	6.7	-3.6	1.0
	46.7	7.4	-4.5	.8
	51.8	7.6	-5.4	1.0
5	42.5	4.3	-2.8	0.9
	46.7	4.9	-3.6	.7
	51.8	5.5	-4.5	.6

Trim angle, τ = 3°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
100	6.8	8.7	23.5	6.4
	8.6	13.7	43.5	6.75
80	6.9	7.4	22.6	5.9
	8.7	10.5	36.6	5.9
	10.1	12.5	34.8	5.65
	11.2	14.5	36.6	5.8
60	6.9	4.9	12.2	5.3
	8.6	7.2	26.1	5.1
	10.1	8.2	27.0	4.8
	11.2	11.1	29.6	5.05
	13.2	12.1	47.8	4.9
	14.6	14.6	62.0	5.0
	23.7	13.8	64.6	3.5
	26.0	12.9	52.4	2.9
	30.1	13.8	26.1	2.5
	36.7	15.7	17.4	2.2
40	6.9	3.1	9.5	4.35
	8.6	4.4	16.4	4.2
	10.3	4.8	18.3	4.1
	11.2	5.7	22.6	4.1
	13.4	7.9	34.8	3.9
	14.5	8.1	41.8	4.0
	15.8	8.7	43.5	3.8
	17.9	8.5	41.8	3.5
	19.0	8.8	41.0	3.4
	19.6	8.1	36.6	3.5
	21.0	8.1	32.3	3.0
	21.7	8.5	31.3	2.8
	23.5	8.7	24.4	2.6
	25.9	9.0	17.5	2.5
	31.2	10.8	11.3	2.1
	36.8	11.9	6.1	1.7
	41.8	12.9	2.5	1.6
20	13.2	3.4	13.8	2.9
	14.2	3.2	13.8	2.6
	15.9	3.5	11.3	2.6
	17.7	3.9	9.5	2.5
	19.0	4.0	8.6	2.4
	19.7	4.5	6.9	2.3
	20.8	4.7	7.2	2.0
	23.6	5.1	5.2	2.05
	26.0	5.8	4.3	1.5
	31.5	6.6	2.6	1.4
	36.5	7.4	-1.1	1.3
	41.7	7.9	-2.0	1.1
	45.8	8.6	-2.7	1.1
10	17.7	2.3	1.7	2.1
	19.2	2.2	1.7	1.55
	20.9	2.7	1.7	1.5
	24.0	2.9	.7	1.5
	25.4	3.5	.7	1.2
	31.3	4.2	-.2	1.2
	36.4	4.8	-1.9	1.1
	42.2	5.0	-2.0	.7
	45.9	5.6	-2.7	.8
	51.4	6.6	-4.5	.65
5	18.9	1.1	0.7	1.5
	20.8	1.5	.7	1.2
	24.0	2.1	-.2	1.1
	26.0	1.9	-.2	.9
	31.7	2.8	-1.1	.7
	36.9	3.0	-1.1	.8
	41.5	4.1	-2.0	.6
	45.8	3.9	-2.0	.8
	51.4	4.9	-3.6	.7

Trim angle, τ = 4°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
60	38.6	13.1	3.4	1.7
40	38.4	9.7	-1.9	1.5
	43.0	11.1	-3.7	1.4
20	38.5	6.6	-3.7	1.1
	43.6	7.6	-4.5	.9
	49.2	8.9	-6.2	.9

Trim angle, τ = 5°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
100	7.1	9.1	-0.2	6.6
	8.9	13.5	21.8	6.7
	9.9	15.0	24.4	6.5
	11.2	17.8	30.6	6.5
80	7.1	7.7	2.5	6.1
	8.9	10.3	15.7	5.8
	10.0	11.5	16.6	5.6
	11.1	13.1	21.8	5.8
	12.5	15.3	30.6	5.75
	13.2	16.3	36.6	5.75
	23.4	14.4	61.1	3.5
	26.9	13.8	28.8	2.8
	29.0	13.9	19.1	2.5

TABLE II (Continued)

Test Data for N.A.C.A. Model No. 11-A Flying-Boat Hull

Kinematic viscosity = 0.00001446 $\frac{ft.^2}{sec.}$

Test dates: April 13-15, 1933
Water temperature: 50° F.
Tank water density: 63.8 lb. per cu.ft.
Trim angle, τ = 5°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
60	7.1	5.5	0.8	5.3
	8.8	7.4	7.0	5.1
	10.0	8.4	9.1	5.0
	12.1	9.1	18.3	4.9
	13.1	10.2	34.1	4.9
	14.8	11.6	54.9	4.8
	16.5	11.8	61.9	4.35
	18.4	11.0	57.6	4.05
	19.9	10.5	46.2	2.7
	21.7	10.2	35.7	3.0
	24.6	10.7	19.2	2.6
	26.7	10.7	14.0	2.25
	28.9	11.5	7.8	2.2
	34.2	11.2	2.6	1.85
	36.2	11.7	-.1	1.85
	39.4	12.6	-3.6	1.5
40	7.4	3.7	-4.4	4.35
	8.6	3.8	-1.9	4.2
	10.1	4.2	2.5	4.0
	12.1	5.2	15.7	4.1
	13.2	5.6	22.7	4.0
	14.7	6.1	28.8	3.8
	16.5	6.3	26.1	3.3
	18.4	6.3	19.9	2.8
	19.8	6.5	13.1	2.75
	21.6	6.2	8.7	2.5
	24.0	6.7	6.1	2.2
	26.7	7.1	3.4	2.0
	28.8	7.7	.8	1.9
	34.0	8.6	-2.8	1.5
	35.2	8.6	-4.4	1.5
	39.2	9.8	-6.3	1.3
	44.2	11.3	-8.0	1.3
20	13.3	2.8	5.1	2.7
	14.7	3.0	5.1	2.5
	16.7	3.1	4.3	2.2
	18.3	3.0	3.4	2.2
	20.0	3.2	1.6	2.1
	21.4	3.4	1.6	1.8
	24.1	3.5	-1.1	1.7
	26.6	4.1	-1.9	1.5
	31.3	5.0	-2.7	1.2
	34.2	5.7	-3.6	1.0
	39.5	7.0	-5.2	1.1
	41.4	7.6	-6.3	1.1
	44.0	7.7	-5.2	.8
	49.8	9.8	-8.0	.9
10	18.2	1.7	0.8	1.7
	20.0	1.8	- .1	1.4
	21.8	2.2	-1.1	1.3
	24.2	2.4	-1.9	1.2
	26.7	2.9	-1.1	1.2
	31.5	3.5	-1.9	1.0
	34.1	4.3	-3.6	.85
	39.0	5.2	-2.8	.8
	44.2	6.2	-4.4	.8
	50.0	7.8	-5.0	.7
5	20.0	1.2	-1.1	1.0
	21.8	1.5	-1.1	.8
	24.3	1.7	-1.1	.9
	26.6	2.0	-1.1	.8
	31.6	3.0	-1.9	.7
	34.0	3.1	-1.1	.7
	35.6	3.2	-1.1	.6
	39.0	5.2	-2.8	.6
	41.2	4.4	-2.8	.8
	44.2	5.0	-2.8	.4
	50.2	6.3	-3.6	.5

Trim angle, τ = 6°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
60	39.9	12.3	-6.9	1.35
40	39.5	10.4	-9.8	1.35
	44.5	12.6	-11.5	1.25
20	39.8	7.6	-7.1	.95
	44.4	9.0	-8.9	.85
	44.7	9.6	-8.9	.85

Trim angle, τ = 7°

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
100	8.5	12.7	-7.0	6.55
	9.7	14.3	-1.7	6.3
	9.8	14.7	.9	6.25
	11.8	17.4	12.1	6.25
80	8.4	10.0	-9.6	5.65
	9.8	11.3	-4.5	5.6
	9.9	11.6	-4.5	5.5
	11.6	11.5	6.0	5.45
	13.1	13.6	28.1	5.4
	15.1	16.1	60.3	5.3
	16.4	16.4	69.9	4.95
	18.4	15.1	65.6	4.5
	20.3	14.7	48.2	3.75
	23.0	14.0	20.2	2.8
	25.2	14.1	9.6	2.7
	30.4	14.3	0	2.1
60	8.5	7.4	-11.4	4.95
	9.9	7.5	-8.7	4.75
	10.0	7.5	-8.0	4.7
	11.4	8.3	- .9	4.7
	13.1	9.4	20.2	4.7
	15.0	10.4	34.9	4.3
	16.8	10.7	34.1	3.95
	18.4	10.4	24.4	3.4
	20.2	10.3	15.8	2.9
	22.8	10.0	6.9	2.55
	25.6	10.6	.9	2.1
	30.4	11.5	-4.4	1.7
	35.7	12.7	-10.5	1.5

TABLE II (Continued)

Test Data for N.A.C.A. Model No. 11-A Flying-Boat Hull

Kinematic viscosity = $0.00001446 \frac{\text{ft.}^2}{\text{sec.}}$

Test dates: April 13-15, 1933
Water temperature: 50° F.
Tank water density: 63.6 lb. per cu.ft.

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
Trim angle, $\tau = 7^\circ$				
40	8.5	4.5	-14.8	4.05
	9.9	4.9	-11.4	3.8
	10.0	5.0	- 9.8	3.8
	11.1	5.1	- 2.8	3.65
	13.1	6.3	7.7	3.55
	15.0	6.5	10.4	3.1
	16.8	6.5	8.7	3.15
	18.4	6.6	3.4	2.7
	20.1	6.7	.9	2.3
	22.8	6.9	- .9	2.05
	25.5	7.3	-2.6	1.7
	29.9	8.2	-6.9	1.35
	35.7	10.0	-11.4	1.4
20	11.4	3.2	-7.1	2.4
	13.3	3.4	-3.6	2.2
	14.6	3.2	-2.7	2.0
	16.9	3.7	- .9	1.9
	18.5	3.7	-1.8	1.95
	20.1	3.9	-2.6	1.7
	22.8	4.2	-4.4	1.5
	25.4	4.9	-4.4	1.3
	30.0	5.9	-6.9	1.05
	35.7	7.8	-8.7	.9
10	16.8	2.3	-1.8	1.3
	18.5	2.5	-1.8	1.5
	20.0	2.9	-1.8	1.3
	22.8	3.2	-3.6	1.1
	25.2	3.6	-3.6	1.0
	30.1	4.8	-4.4	1.0
	36.0	6.2	-6.2	.8
5	18.5	1.9	-0.9	1.1
	23.0	2.5	-2.6	1.0
	25.4	2.8	-2.6	.6
	25.5	2.9	-2.6	.7
	30.1	4.4	-3.6	.7
Trim angle, $\tau = 9^\circ$				
100	11.2	15.8	-20.2	5.9
	12.7	16.9	+ 2.6	5.8
	13.6	18.0	14.8	5.7
	15.6	21.5	62.1	5.7
	17.0	21.6	69.1	5.2
	19.1	20.9	57.6	4.3
	21.0	20.4	43.8	3.7

Load lb.	Speed f.p.s.	Resistance lb.	Trimming moment lb.-ft.	Draft at step in.
Trim angle, $\tau = 9^\circ$				
80	11.2	12.1	-20.2	5.15
	12.8	13.0	2.6	5.2
	14.0	14.8	23.6	5.1
	15.5	15.7	35.8	4.7
	17.5	16.1	35.8	4.0
	19.5	16.1	20.9	3.5
	21.3	15.8	9.6	2.9
60	11.3	8.8	-18.4	4.3
	12.0	9.2	- 3.5	4.4
	14.0	10.8	9.6	4.0
	15.6	11.3	12.1	3.5
	17.9	11.8	6.9	2.9
	19.7	11.7	2.6	2.5
	21.4	11.9	- 1.8	2.4
40	11.3	6.2	-14.9	3.15
	12.3	6.8	-7.9	3.2
	13.8	7.0	-3.6	2.9
	15.8	7.4	-3.5	2.3
	17.9	7.7	-3.6	2.2
	19.0	7.7	-3.6	2.3
	21.1	8.1	-4.4	1.85
20	16.0	4.0	-6.2	1.5
	17.7	4.3	-6.2	1.5
	19.0	4.6	-6.2	1.7
	21.0	5.0	-6.2	1.3
10	18.0	2.8	-6.2	1.25
	19.3	3.0	-6.2	1.1
	21.0	3.3	-6.2	1.0
5	19.4	1.6	-6.2	.4
Trim angle, $\tau = 10^\circ$				
100	13.9	19.0	14.9	5.45
	15.6	21.3	48.1	5.15
	17.4	21.7	49.0	4.75
	18.8	21.6	38.5	4.15
	20.2	21.7	24.5	3.35
80	13.9	15.1	10.4	4.65
	15.6	16.5	21.9	4.35
	17.4	17.1	18.3	3.65
	18.9	16.9	10.4	3.15
	21.0	16.7	3.5	2.85
Trim angle, $\tau = 11^\circ$				
100	13.8	19.5	-.1	5.35
	15.9	22.2	30.7	4.65
	17.2	22.3	31.6	4.25

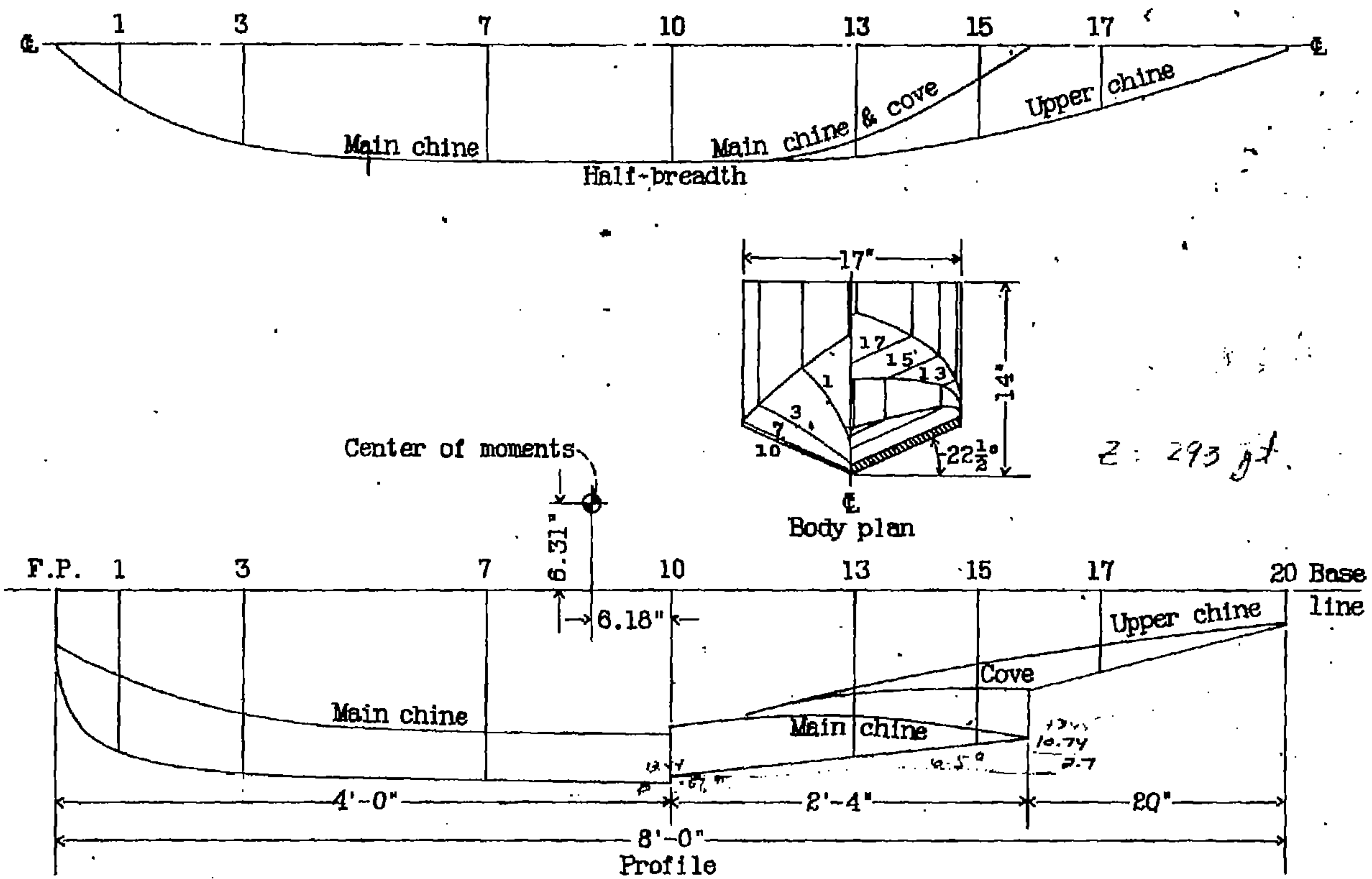


Figure 1.- Lines of N.A.C.A. Model No.11-A

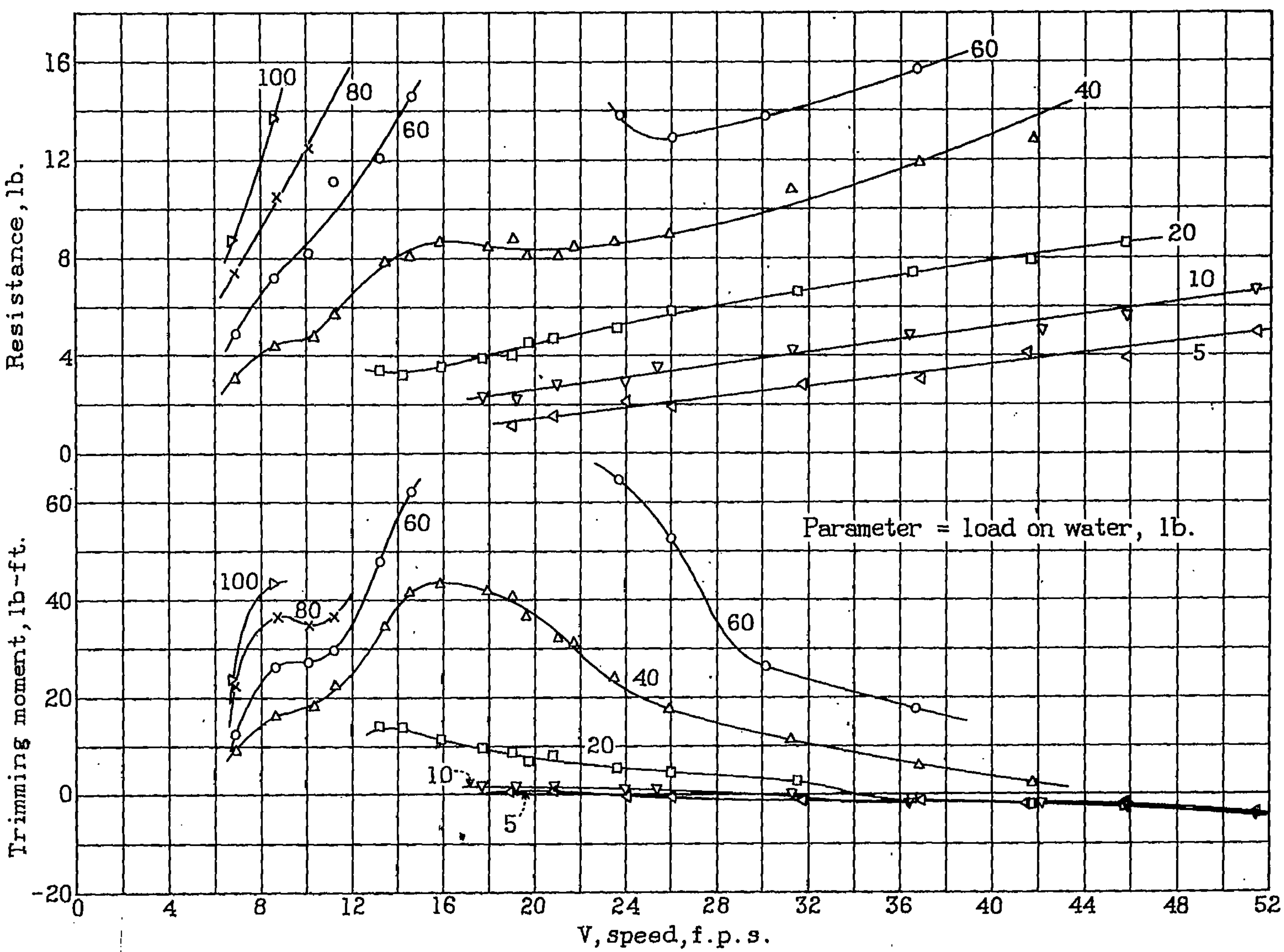


Figure 2.- Curves of resistance and trimming moment. Trim angle τ = 3°

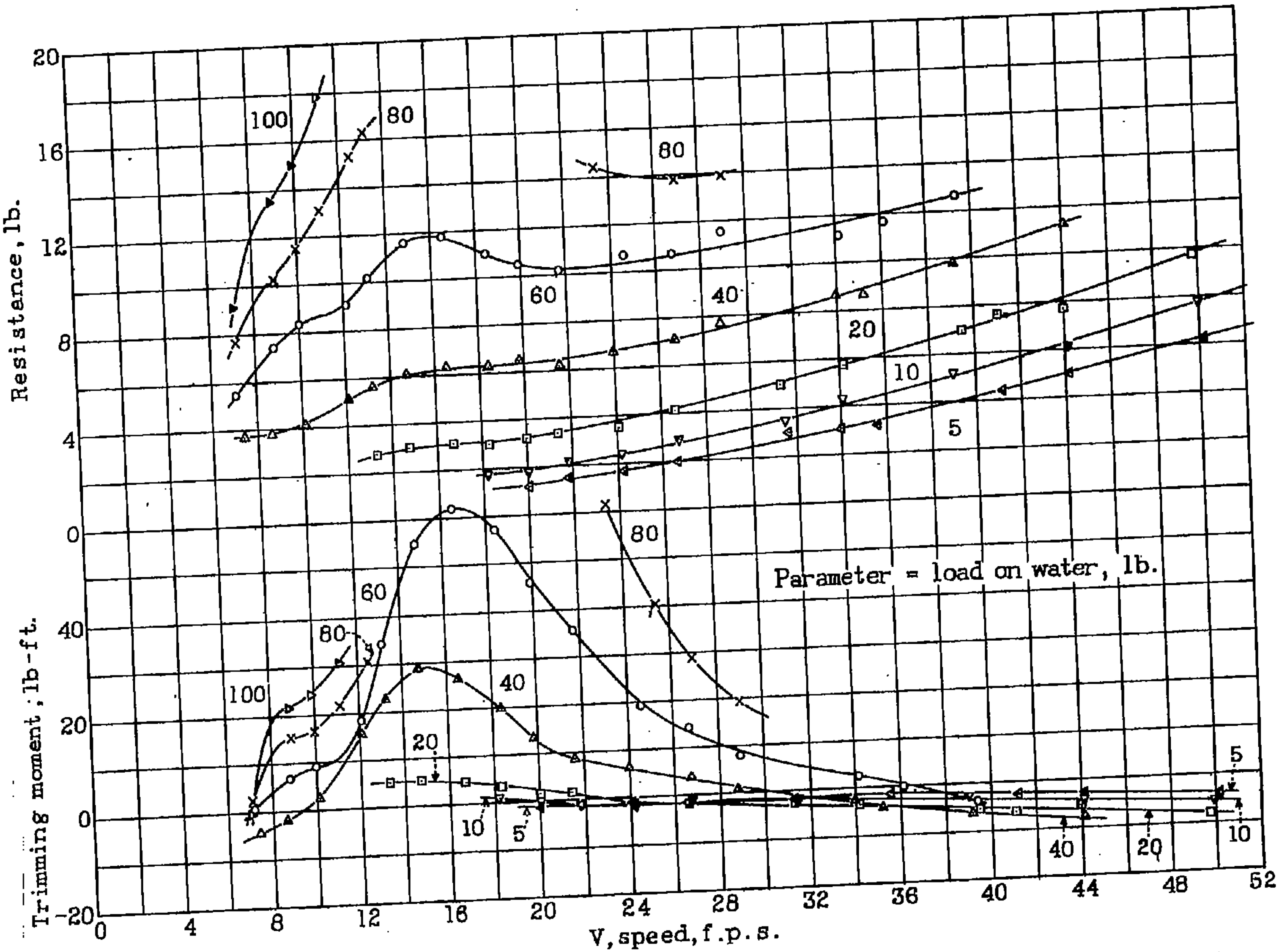


Figure 3.- Curves of resistance and trimming moment. $\tau = 5°$

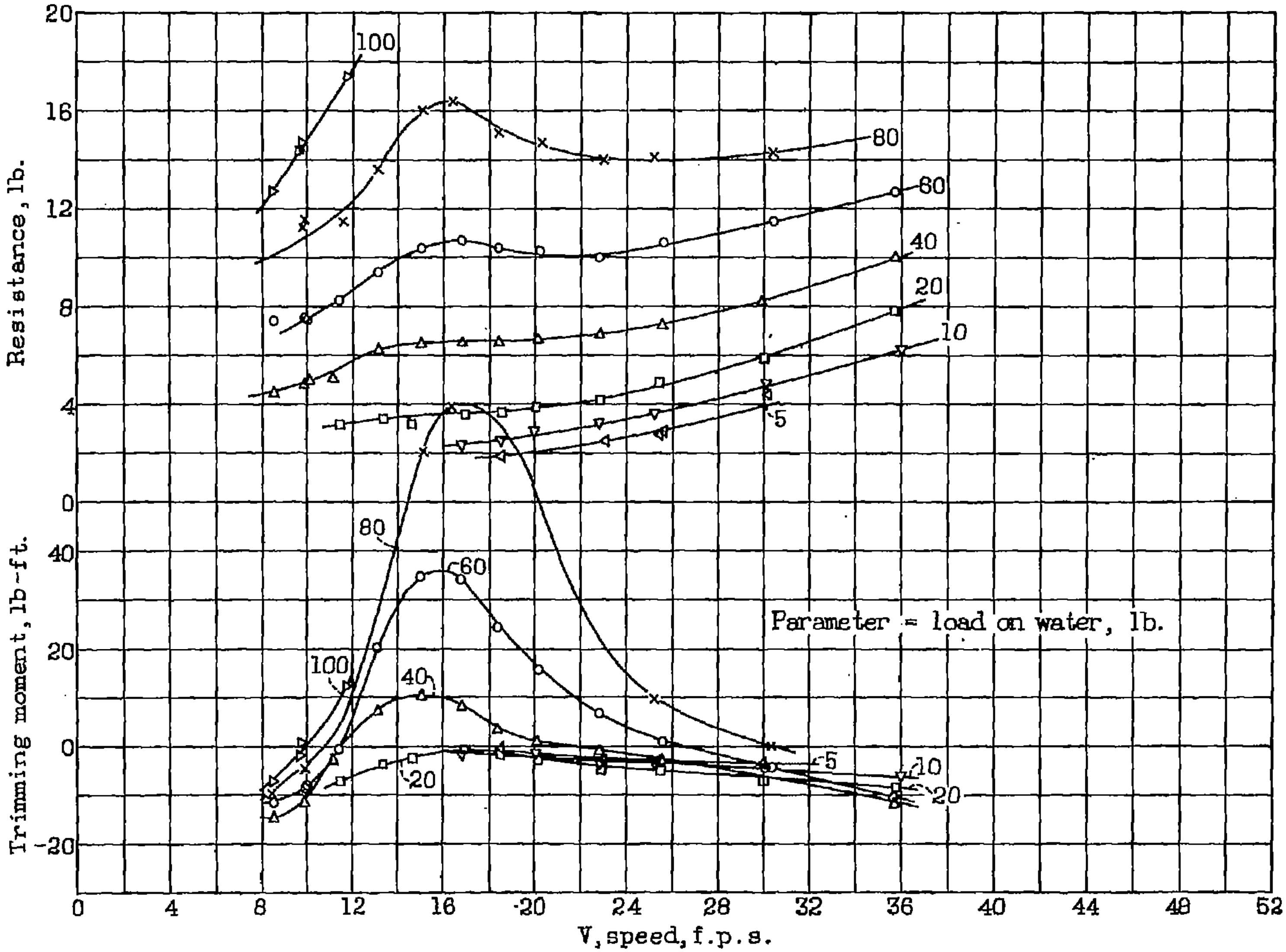


Figure 4.- Curves of resistance and trimming moment. τ = 7°.

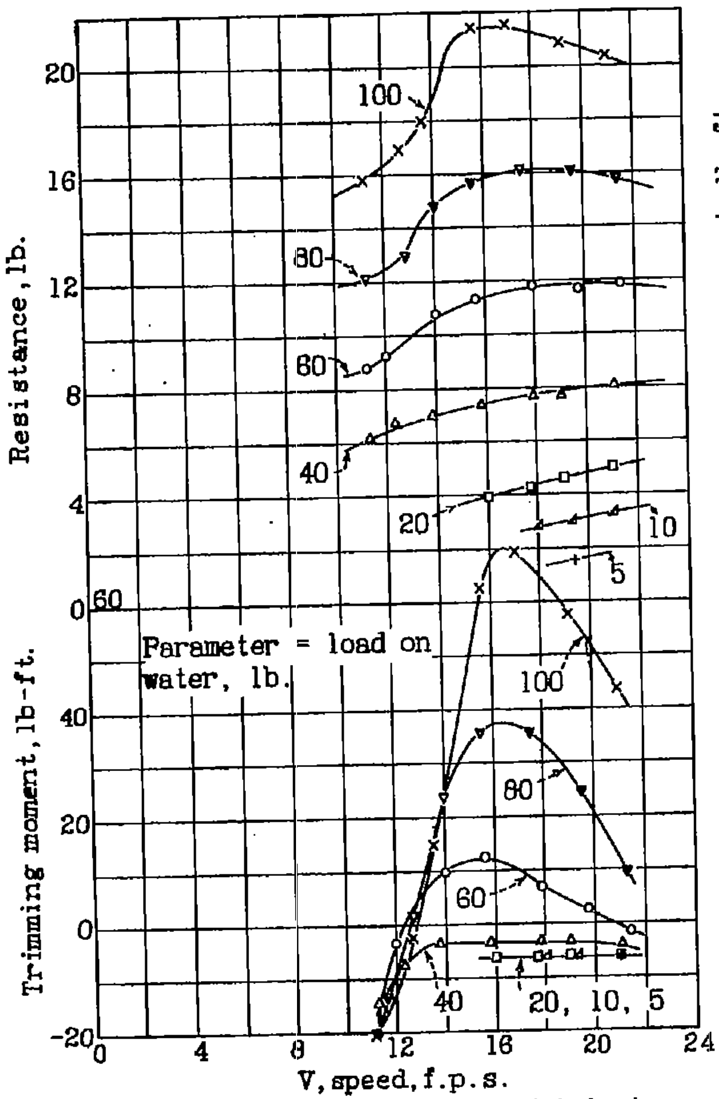
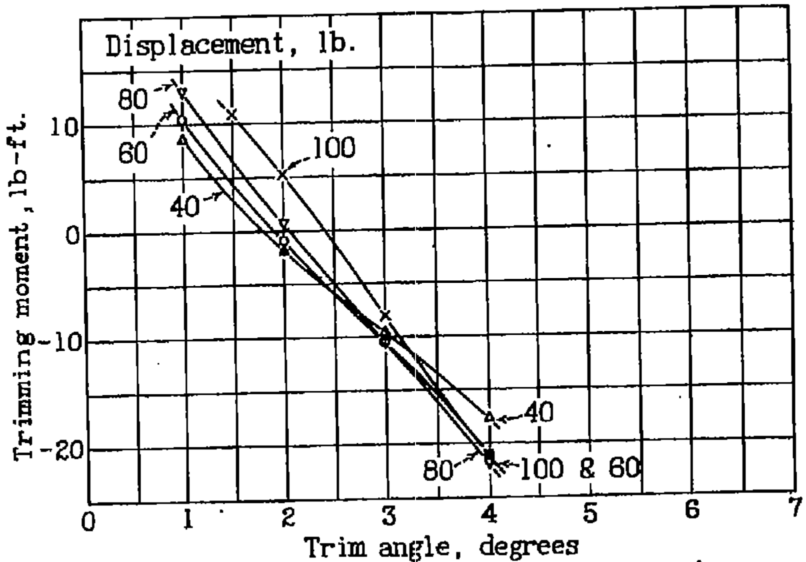


Figure 5.-Curves of resistance and trimming moment. τ = 9°



Note:-Positive moment-Bow tends to rise.
Figure 7.-Trimming moments at rest.

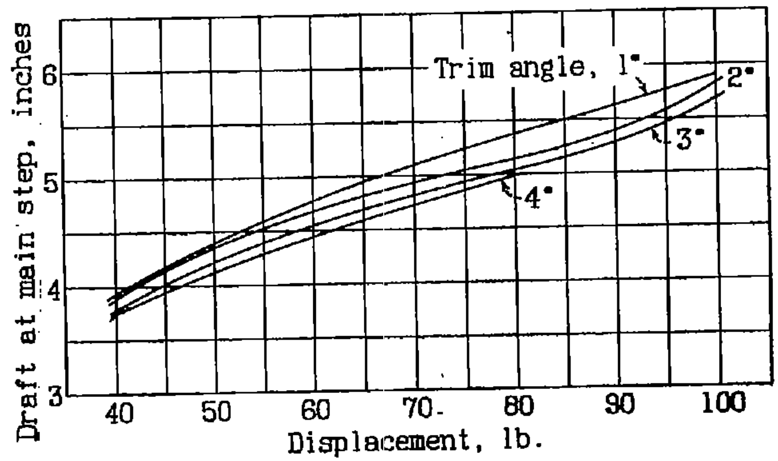
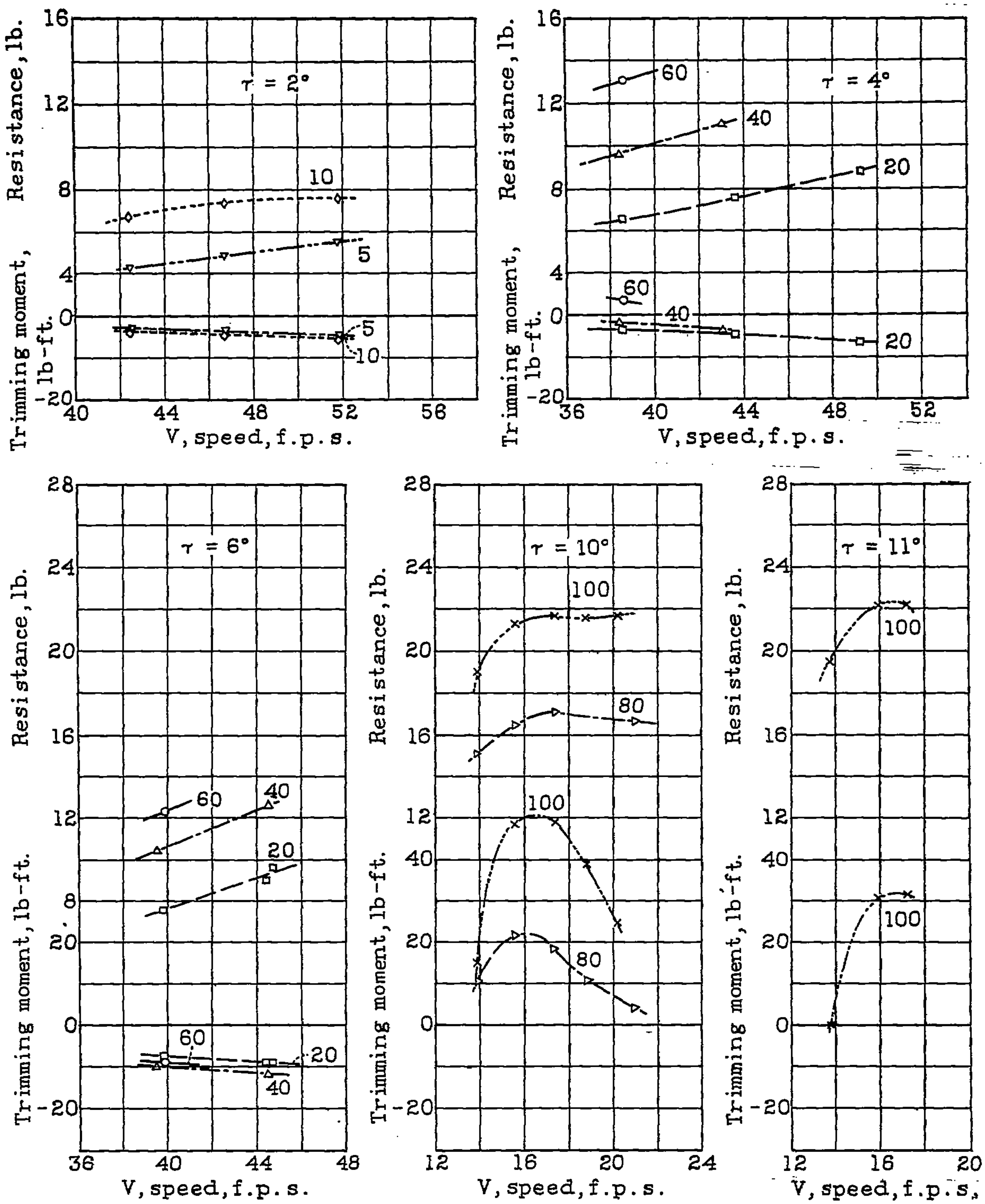


Figure 8.-Drafts at rest.



Parameter = load on water, lb.

Figure 6.- Curves of resistance and trimming moment. $\tau = 2°, 4°, 6°, 10°$, and $11°$.

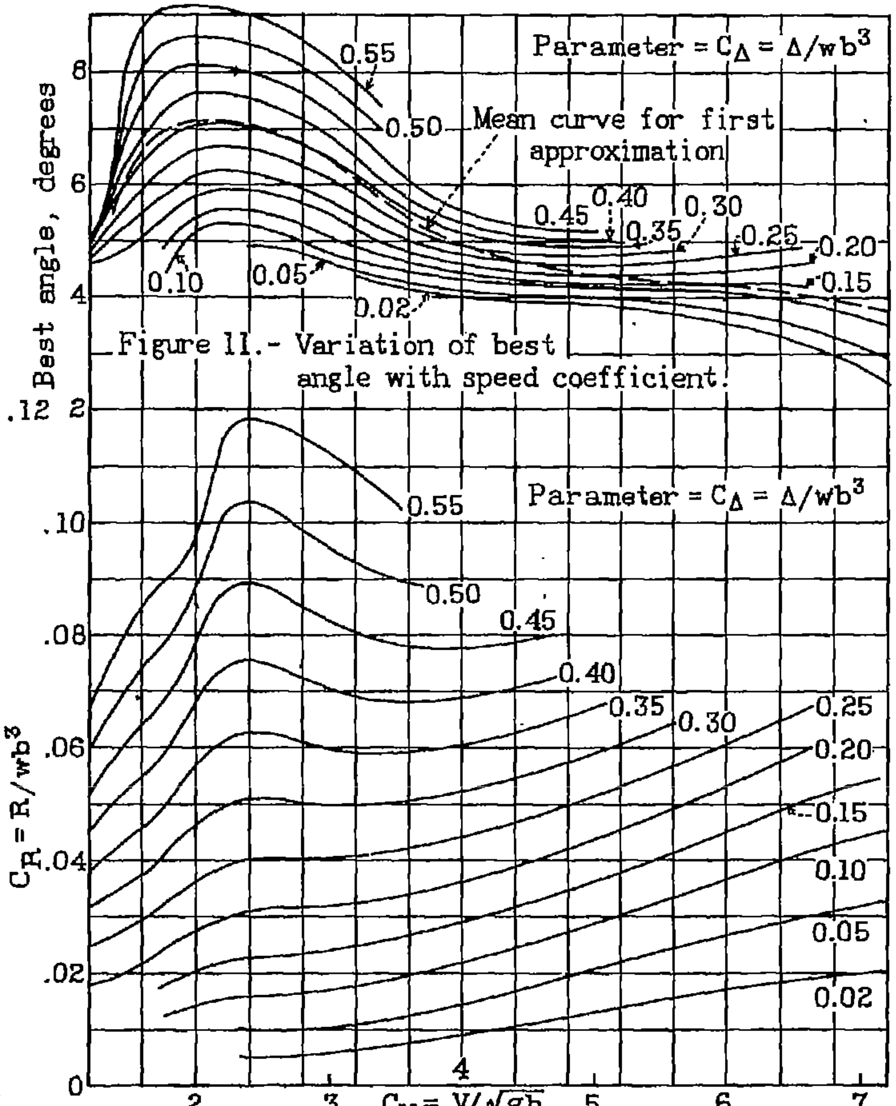


Figure 11.- Variation of best angle with speed coefficient.

Figure 9.- Variation of resistance coefficient at best angle with speed coefficient.

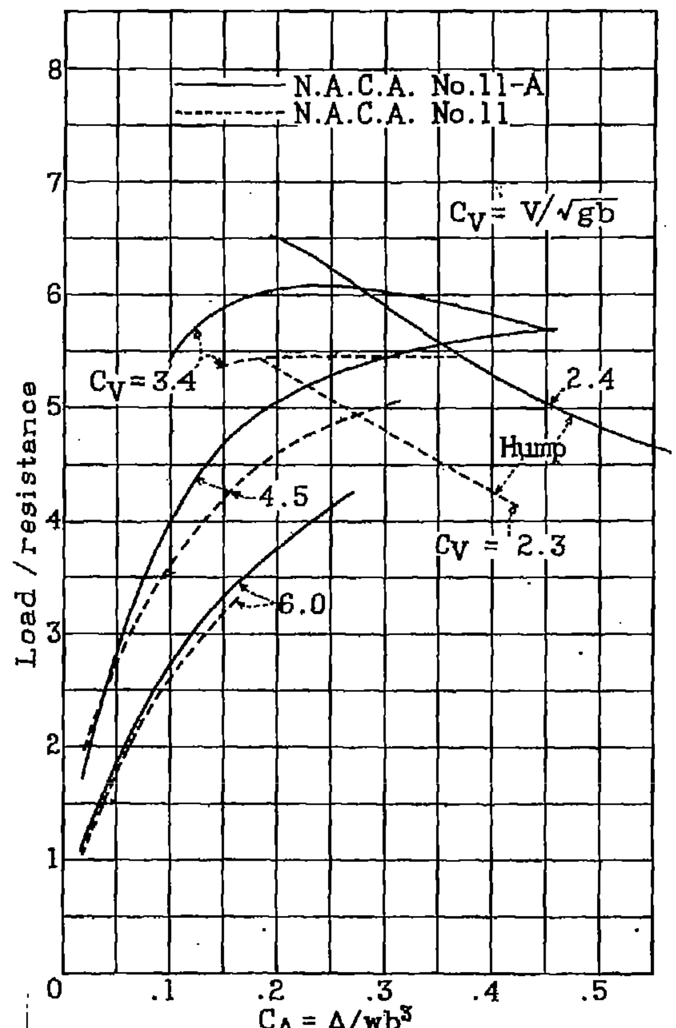


Figure 12.- Load / resistance for Model No.11 and Model No.11-A for various values of speed coefficient.

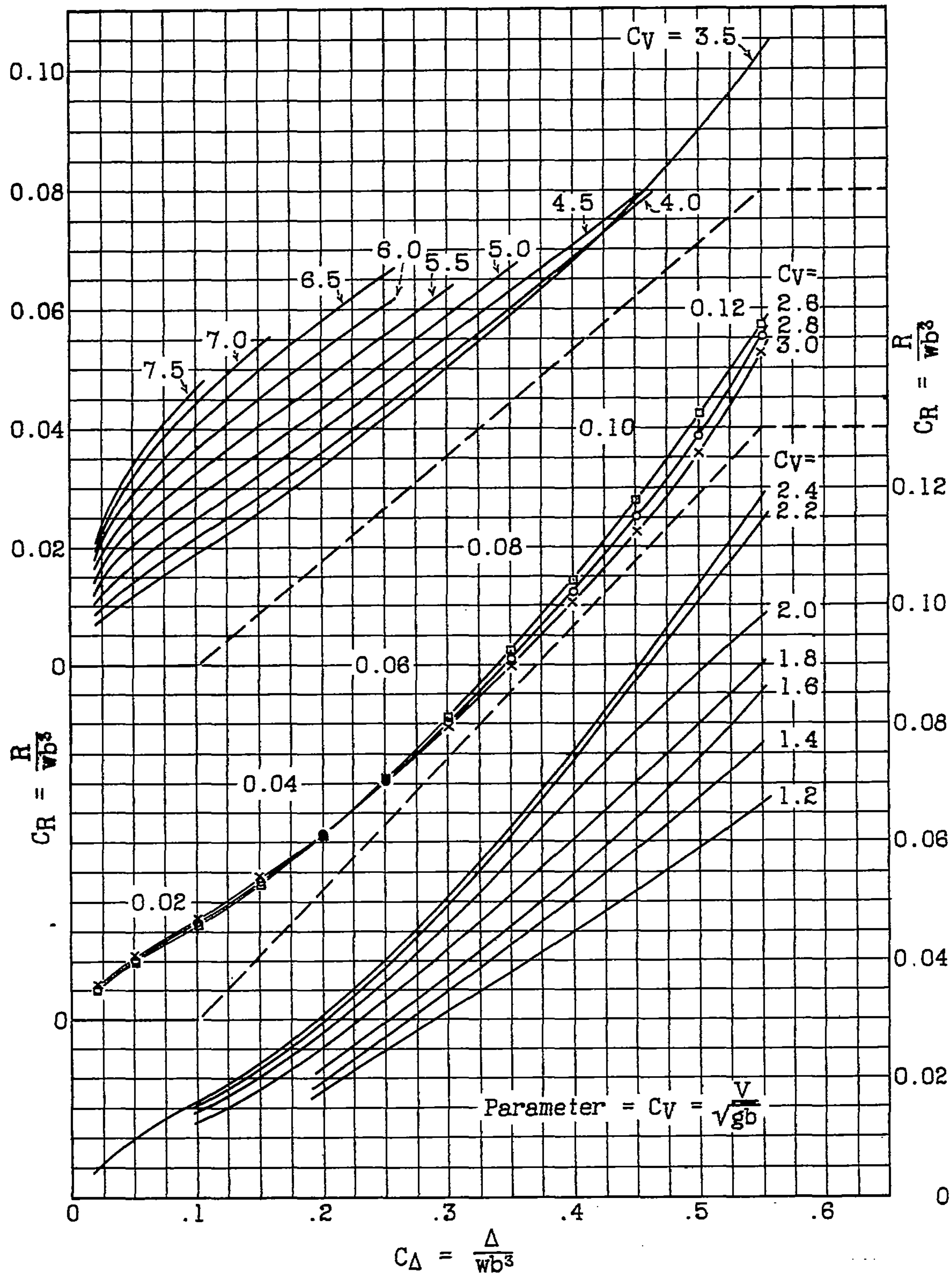
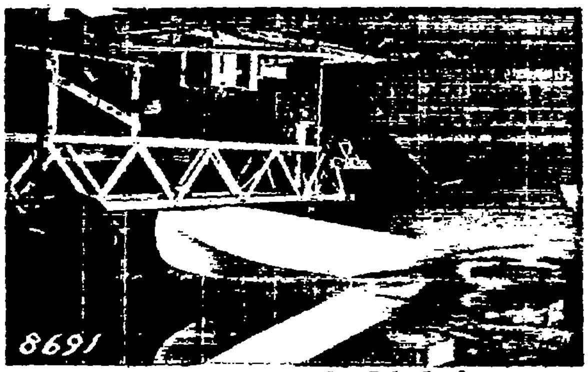
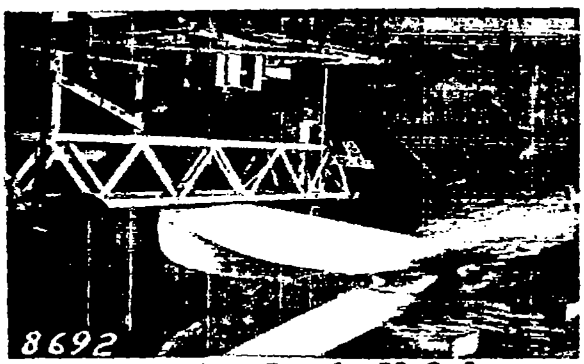


Figure 10.-Variation of resistance coefficient at best angle with load coefficient.

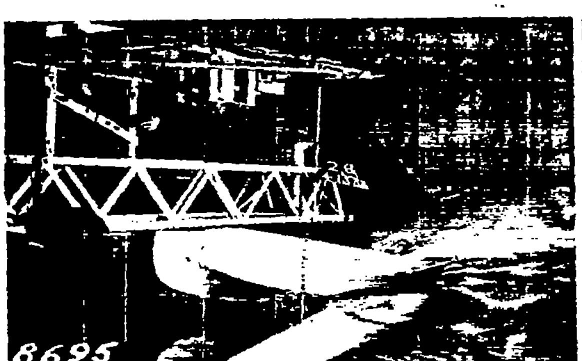
Model No. 11-A



Load 40 lb., Speed, 16.6 f.p.s.

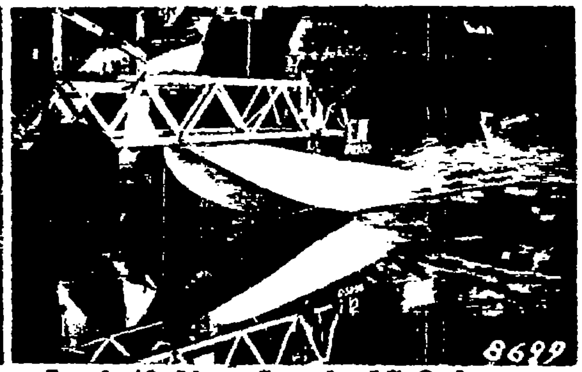


Load 40 lb., Speed, 20.2 f.p.s.

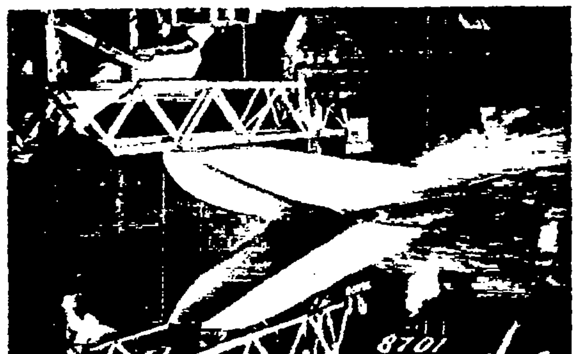


Load 80 lb., Speed, 19.5 f.p.s.

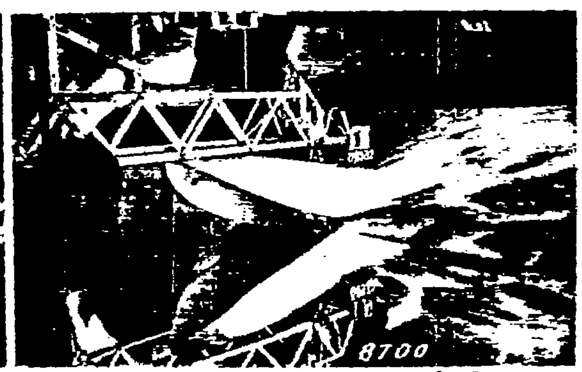
Model No. 11



Load 40 lb., Speed, 17.2 f.p.s.



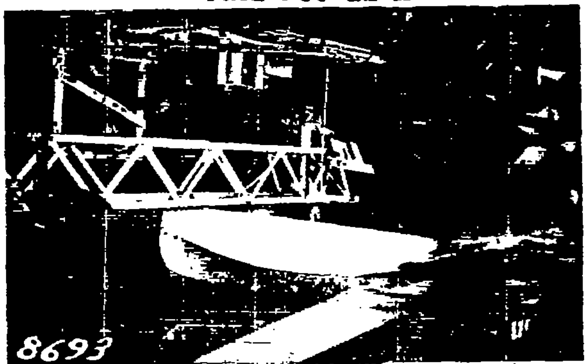
Load 40 lb., Speed, 21.0 f.p.s.



Load 70 lb., Speed, 19.0 f.p.s.

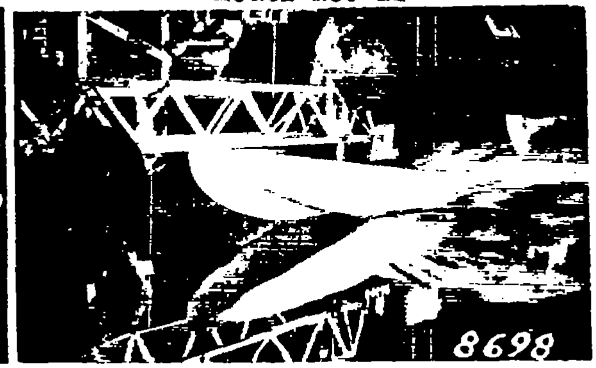
Figure 13.-Spray photographs at 9° trim angle.

Model No. 11-A

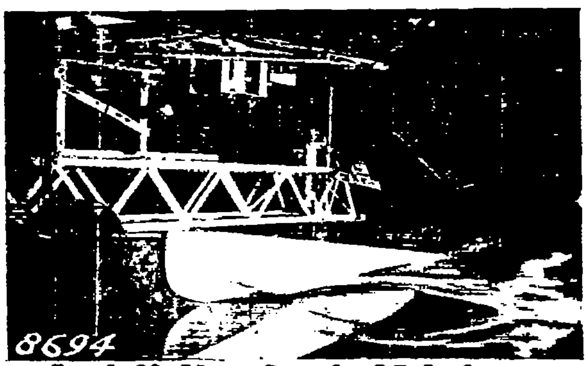


Load 40 lb., Speed, 18.4 f.p.s.

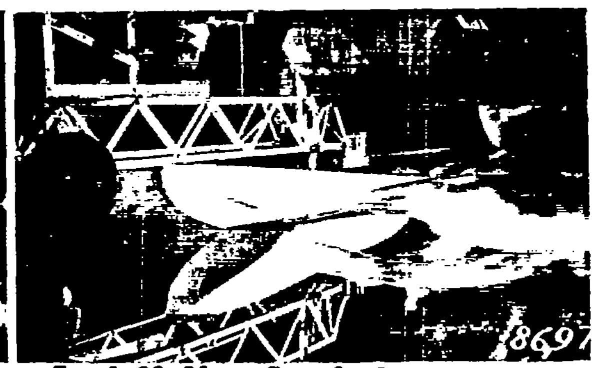
Model No. 11



Load 40 lb., Speed, 17.2 f.p.s.



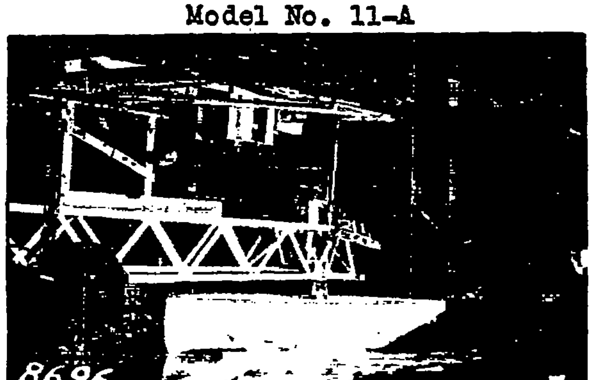
Load 80 lb., Speed, 15.1 f.p.s.



Load 80 lb., Speed, 13.7 f.p.s.

Figure 14.-Spray photographs at 7° trim angle.

Model No. 11-A



Load 100 lb., Speed, 7 f.p.s.

Figure 15.-Spray photograph at 3° trim angle.